TIDGET™ Mayday System for Motorists

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ABSTRACT

The development of an effective motorist Mayday system for travelers in rural and urban parts of the United States and Canada has been hampered by the lack of an infrastructure to receive and process emergency requests and by the inability of most motorists to precisely define the location of their vehicle. The development of intelligent vehicle-highway systems and an expanded network of computer-switched radio systems will greatly improve the ability of highway agencies, both public and private, to respond to emergency requests. The missing element is still an inexpensive and reliable means of determining the location of vehicles in distress. The requirements for a viable motorist Mayday service are: low cost, reliable response, and automatic linking to a two-way radio service.

GPS has been proposed as a potential method of providing location in support of a Mayday service. However, the expense of a conventional GPS receiver will prohibit widespread installation on vehicles. One market source has indicated that the total cost to the user must be less than $100 before the system would be widely used. Also, the time-to-first-fix of a GPS receiver is unacceptable for use in an emergency situation unless the receiver is continually operating. Finally, the inability of a receiver to compute a navigation fix except when four satellites are in view makes this a poor system design for operation in mountainous or urban regions where there is poor satellite visibility.

NAVSYS has developed a low cost GPS sensor, the TIDGET™, which solves these problems for a GPS Mayday service. The TIDGET sensor does not track the GPS signals, but instead captures a brief "snapshot" of raw GPS sampled data. This "snapshot" is transmitted to the emergency dispatch facility where it is processed to compute the location of the motorist. The processing also includes aiding data from a map database to allow the vehicle's location to be determined when fewer than four satellites are in view of the sensor. In large quantities, the TIDGET sensor cost is reduced to less than $50 a unit (not including the communications link). The TIDGET requires no initialization or warm-up time, since the data processing functions are not performed at the vehicle. The sophisticated software used to process this message at the dispatch center allows the solution to be derived in many cases when only two GPS satellites are in view.

This paper includes a description of the TIDGET Mayday system and presents preliminary test results demonstrating the ability to locate a stranded motorist using this low cost GPS sensor.

INTRODUCTION

Applications for global positioning systems (GPS) have expanded to many unique areas that were unthought of only a few years ago. One that is still not given wide crediblity is the potential for equipping every vehicle on the roadway, both commercial and non-commercial, with a GPS receiver for Mayday applications.

The benefits of equipping every vehicle on the road with a geolocation device and a radio link to an infrastructure capable of processing requests for assistance are plain enough. In addition to faster detection and response for accidents, medical emergencies, and disabled vehicles, a reliable Mayday system has a very real value in providing a peace of mind that few other automobile safety systems can. Although difficult to quantify, this peace of mind may be the basis of support for the largest application of GPS yet envisioned—literally GPS by the millions.

There are three major obstacles to establishing a viable Mayday network across North America:

- Creating an organizational infrastructure to coordinate the activities of the many agencies, both public and private, that must cooperate in establishing a network;
- Defining a communications link between the vehicle and the roadway; and

A short (~1 kbyte) "snapshot" of the GPS data in a digital data buffer (DDB), and transmits the raw data back to the Operations Center for processing.

When an emergency message is received, the TIDGET data in the message is processed to extract the satellite code phase and carrier frequency observations. A reference GPS receiver at the Operations Center is used to provide data on the visible GPS satellites and compute the TIDGET location from the satellite observations. A digital map is also maintained at the Operations Center. Data from this map is used to "aid" the TIDGET navigation solution, allowing the vehicle location to be determined in most cases using only two satellite observations [3,4,5].

The TIDGET has the following advantages over a conventional GPS receiver for emergency vehicle location:

Sensor Cost The simple design adopted by the TIDGET reduces the sensor component count to almost one-third that of a conventional receiver. This results in a similar savings in cost. The TIDGET currently costs less than $100 per unit—one third the cost of an OEM GPS receiver. TIDGET sensor prices are projected to drop to less than $50 within a year for large quantity purchases. The TIDGET is ideally suited for applications such as emergency location that are highly cost-sensitive.

No Initialization A conventional GPS receiver must go through an extensive initialization procedure before a navigation solution can be computed. The receiver must first search for the visible GPS satellites, lock onto their signals, and then demodulate the navigation message broadcast by the satellites. This procedure takes a minimum of 30 seconds to perform and can take 15 minutes or longer if the current location of either the vehicle or the satellite is not known. The time-to-first-fix (TTFF) can be a significant obstacle for an emergency service where it is imperative that the location data is available immediately to allow prompt dispatching of assistance.

The TIDGET takes less than 1 second to turn on, capture a snapshot of data, and send this data back to the Operations Center. The TIDGET processing workstation developed by NAVSYS can process the TIDGET data to determine a solution for the vehicle within a few seconds. This rapid acquisition is achieved by using timing data from the communication link and satellite data from the Operations Center’s reference GPS receiver to reduce the search and acquisition process. The TIDGET architecture therefore minimizes the delay time in determining the current vehicle location from the GPS satellite measurements.

Reliable Operation The emergency location sensor will not be used frequently, but when it is used, it is critical that the sensor operates reliably. GPS receivers have made significant advances in recent years to improve their reliability and ease of operation. However, tracking and processing the GPS satellite signals is a complicated process, and there are a lot of factors that can cause a receiver to have difficulties computing a navigation solution. If the receiver is slow to acquire and track the satellites, the emergency response could be delayed. If the accident happens in a location where four GPS satellites are not visible, a standard GPS receiver might never be able to provide the vehicle location.

The TIDGET design provides significantly more reliable operation than a conventional receiver for the following reasons:

- The simplicity of the TIDGET sensor design (fewer parts, no processing) means that there is less potential for failure.

- The TIDGET data is processed at the Operations Center, so that no acquisition or tracking is performed at the vehicle.

- By taking advantage of aiding data from digital maps, a navigation solution can be computed from the TIDGET data even when four satellites are not visible. This increases the reliability of the emergency service when operating in a city or in mountainous regions where the satellite signals might be blocked.
• Reducing the overall cost of the system to a level low enough to be marketable to the average consumer.

In the last several years, significant progress has been made in all three of these areas [1].

The Mayday system under development by NAVSYS was designed to have the following features:

• Interoperability with a variety of mobile communications links.

• Central processing to assist interoperability, minimize costs, and route mobile calls to the appropriate response facility.

• Minimize the cost of the in-vehicle sensor using the NAVSYS TIDGET sensor technology.

• Improve GPS coverage and performance through signal processing and aiding at the dispatch facility.

The system architecture adopted for the TIDGET Mayday system provides an effective method of locating vehicles in need of assistance at an equipment price that is attractive to consumers. NAVSYS is currently pursuing the development of a Mayday system with the Colorado Department of Transportation (CDOT) for operation in the State of Colorado.

TIDGET MAYDAY SYSTEM ARCHITECTURE

The TIDGET Mayday system architecture is illustrated in Figure 1. The system includes the following elements:

TIDGET Sensor The TIDGET sensor is used to provide the GPS data from which the vehicle location can be derived.

Mayday Terminal The Mayday terminal installed on the vehicle provides the two-way data link from the vehicle to the Operations Center. This terminal is integrated with the TIDGET sensor to access the location data. The terminal is also used to call for help and display messages to the motorist from the Operations Center.

Operations Center The Mayday Operations Center includes the TIDGET processing system which determines the vehicle location from the TIDGET data. The Operations Center also places priorities on the calls, routes call for assistance to the appropriate agency (e.g. state police, AAA, towing service, or medical facility), and notifies the motorist of the action taken and the anticipated response time.

TIDGET TRACKING SENSOR

The TIDGET sensor was developed by NAVSYS specifically for tracking applications [2,5]. It uses GPS satellite signals to provide data to the Mayday Operations Center on the location of the vehicle. Because the sensor employs a much simpler architecture than that of a classic GPS receiver, it achieves a significantly lower cost and better performance for emergency location.

A number of manufacturers, such as Rockwell, Motorola, and Trimble, offer OEM GPS card products that adopt the digital architecture illustrated in Figure 2. These cards include the hardware to receive the GPS satellite signals and convert them to a digital data stream through a down-conversion and sampling process. The satellite signals are then processed digitally using a custom ASIC, and the measurements of the pseudo-range and carrier frequency are used in a microprocessor to derive the navigation solution. In an emergency location application, the OEM card would output the vehicle coordinates (latitude, longitude, altitude) across an RS-232 interface for transmission back to the Operations Center.

As illustrated in Figure 2, the TIDGET sensor architecture is significantly simpler than a conventional GPS receiver. Instead of processing the GPS data on the vehicle, the TIDGET simply converts the GPS satellite signals into a digital data stream. When the device is triggered (e.g. by an air-bag sensor or keypad), the TIDGET captures a
ALTERNATIVE COMMUNICATION LINKS

The regions that would benefit most from a Mayday service are the rural areas. When an accident happens, or a medical emergency occurs, these are the areas where assistance from other motorists cannot be relied on. A significant number of lives could be saved if vehicles were equipped to make Mayday calls automatically following an accident. This would allow emergency services to be dispatched promptly to an unconscious driver in need of critical assistance. Such an emergency could occur, for example, after a car skidded off the road due to ice or snow.

A major problem that remains to be solved in the United States is the lack of a mobile communications infrastructure that covers 100% of the country. Table 1 lists some of the candidate mobile communications services that could be used to support a Mayday service. All these services have been concentrating their coverage in the most densely populated regions. Currently, rural coverage is at best spotty and in many locations is non-existent. However, the mobile communications market is growing rapidly and service is expanding beyond the major metropolitan areas. A public-private partnership with Federal cost-sharing may be the additional incentive required for the development of a Mayday system infrastructure. In the interim, the best approach for a Mayday service is to design the system so that a large variety of mobile communication links can be supported. This allows the consumer to select the service most appropriate for his or her needs.

**Cellular Telephone**

The cellular telephone network provides the most extensive mobile communications infrastructure nationwide. Based on studies by United Parcel Service, cellular provides the best coverage of any mobile data service available in rural regions. Data can be transmitted over cellular links using a conventional modem protocol. Cellular calls are routed from the cell site to a mobile telephone switching office (MTSO) and then are sent to an Operations Center through normal phone lines.

Devices are available that allow a modem to be plugged into the connector that many hand-held phones provide for hands-free operation. This allows a Mayday call to be automatically dialed through the cellular phone when an accident occurs. Through the use of an 800 number, calls can automatically be routed through the telephone system to the nearest Operations Center. The TIDGET data can be used to locate the vehicle and the handset can then be returned to voice-only to allow the dispatcher to talk to the driver. For automobiles already equipped with cellular phones, this architecture provides a very inexpensive method of adding a Mayday location and emergency autodialing capability.

**Packet-Radio**

Packet radio networks provide an inexpensive two-way messaging capability (data only, no voice). Data sent from the terminal is broken into packets to which addressing information is added. Packets are transmitted through the radio network and land lines to the end-address. Typically, a delay of 6-12 seconds occurs between transmission and response.

The two major suppliers of two-way packet-switched services are Ardis and RAM. Both have extensive nationwide networks concentrated in the metropolitan regions. Ardis was developed as a joint effort between IBM and Motorola and uses a Motorola proprietary

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Major Service Providers</th>
<th>Coverage Area</th>
<th>Typical Equipment Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular</td>
<td>numerous</td>
<td>Nationwide</td>
<td>$935</td>
</tr>
<tr>
<td>Packet-switched</td>
<td>Ardis</td>
<td>Nationwide</td>
<td>$1500</td>
</tr>
<tr>
<td></td>
<td>Ram</td>
<td>Nationwide</td>
<td>$995</td>
</tr>
<tr>
<td>SMR</td>
<td>Nextel</td>
<td>CA, NY, Chicago, Dallas, Houston</td>
<td>$700-800 installed</td>
</tr>
<tr>
<td></td>
<td>Cencall</td>
<td>Nationwide (under devel)</td>
<td>$1500</td>
</tr>
<tr>
<td>Satellite</td>
<td>AMSC</td>
<td>US (100%)</td>
<td>$2000 (1994)</td>
</tr>
<tr>
<td></td>
<td>Qualcomm</td>
<td>US (100%)</td>
<td>$4500 per vehicle monthly service</td>
</tr>
</tbody>
</table>
network. RAM was developed by Bell South and Ram Mobile Data and uses an open architecture network designed by GE Ericsson.

Packet-switched networks provide an inexpensive mobile communication link for short messages. As such, they are well suited for use in a Mayday system.

**Specialized Mobile Radio (SMR)**

Specialized mobile radio (SMR) systems are mainly used for commercial operations such as taxis and delivery fleets. SMR networks carry data, voice, and dispatch service signals, thus offering more options for their clients than cellular or packet radio. SMR services are provided by a number of organizations.

Nextel Communications Inc, which changed its name from FleetCall in April 1993, operates an SMR network including California, New York, Chicago, Dallas, and Houston. The service’s existing infrastructure, since its recent merger with Dispatch Communications, can reach up to 105 million people.

CenCall Inc is part of a consortium which is building a nationwide system. CenCall has grown significantly in the last year through acquisitions and recently went public.

Mobile terminals are available for these services that include standard RS-232 interfaces for mobile data transmission. This equipment can be integrated with the TIDGET sensor for use in emergency location.

**Satellite Communications**

A number of mobile satellite communication services are currently under development. Satellite communications have the advantage of being able to cover large geographic areas. However, these systems are very expensive to install and, to date, the communication terminals are very costly.

The American Mobile Satellite Consortium (AMSC) provides a commercial mobile satellite service using geostationary satellites. Dual-mode terminals are being developed that will allow operation on both the AMSC satellite link and other networks such as cellular or SMR. This will allow the AMSC service to be used to fill in the coverage gaps in rural areas. This system has potential for application in a Mayday service, but the equipment is currently too expensive for widespread use.

Qualcomm currently operates a vehicle location service using a geostationary satellite link. This provides continuous coverage over the United States. The equipment is mostly used by trucking fleets and is not suited to automobile installation due to the size and cost of the terminals.

Orbital Sciences Corporation plans to launch a packet-switched satellite communications service, Orbcomm. The terminals are projected to be very inexpensive and will provide both a two-way messaging capability and rough location data. This service is planned to use low earth orbiting (LEO) satellites. A disadvantage of LEO constellations is the variable coverage provided at different locations and different times of day. Although, on average, the satellite constellation will provide complete nationwide coverage, there can be significant periods (e.g. 10 minutes) when a terminal has to wait until a satellite is in range. This is a frequent occurrence when operating in mountainous regions.

Motorola is planning to launch a mobile satellite service, Iridium, which will operate in conjunction with the cellular telephone service. Iridium will include a more extensive satellite constellation than Orbcomm, and so will provide better service coverage. This will be a good candidate for a Mayday service once it is operational. However, Motorola has not yet received FCC approval or full funding for this project, so there is not yet a firm availability date for this service.

Mobile satellite services will be an attractive alternative for Mayday systems in the future, but the current size and cost of equipment will prohibit their use for this application in the near term.

**Operations Center**

The Operations Center performs the following functions:

- Receiving the incoming calls from the different mobile communication systems
- Interpreting the data structures passed from the different systems
- Processing the TIDGET data
- Identifying the proper agency to handle the call
- Routing the call to the appropriate dispatcher with the location of the vehicle.

A centralized, rather than local system, is proposed to handle routing of calls to the appropriate dispatcher. This is required due to the size of the mobile communication service areas. For example, the Colorado State Patrol central dispatch facility, which is set up to receive cellular 911 calls from the cellular service providers, receives calls
from all over the State of Colorado and also occasionally from Wyoming. The location data provided by the TIDGET sensors will allow the location of the call to be determined and routed automatically to the appropriate state or local agency.

Once the call is routed to the dispatcher, the location of the vehicle is displayed on a digital map of the region using a Geographic Information System (GIS). The dispatcher is connected to the vehicle driver to verify the type of assistance and priority of the call. Using the GIS, the dispatcher can identify the nearest emergency facility to assist the driver and provide an estimated time of arrival. After passing this information on to the driver, the call can be disconnected or, in a critical situation, routed to the emergency vehicle dispatched to the scene to collect further information.

Because of the global coverage provided by GPS, it is possible to use a single Operations Center to cover a large geographic area, for example statewide or even nationwide. In the test program to be conducted with CDOT, a single Operations Center at the Colorado State Patrol facility in Denver will be used initially to cover northern Colorado. As the service area expands in Colorado and into other states, a trade will need to be made between state or national facilities, based on operational and institutional issues.

**TEST RESULTS**

To test the proposed TIDGET Mayday System, a prototype TIDGET was installed in a test vehicle and a TIDGET processing workstation was installed at NAVSYS facilities. Roughly 700 data packets were collected for analysis from the car equipped with the TIDGET sensor while it drove a test route through Colorado Springs. Between 4 and 6 satellites were tracked on each packet, and the position between the reference receiver and the TIDGET sensor was calculated. Knowing the position of the reference station, the position of the TIDGET sensor was determined.

Since each of the 700 data packets includes the position of the TIDGET sensor, each packet is independent of the others. Plotting the positions should produce an outline of the route taken, which should match up with a standard road map of the roads which were used.

The results of the demonstration test are shown in Figure 3. The mapping package used was a PC-based GIS mapping system called MapInfo. A digital road map of the area was provided by CDOT. As can be seen in Figure 3, the data collected from the TIDGET sensor overlaid very precisely on top of the road map. In addition, by using some of the GIS functions provided by MapInfo, the names of the streets traveled and the approximate speed of the vehicle were determined.

In a Mayday application, each time the TIDGET sensor is triggered, automatically or manually, a data packet would be sent via the communications link to the Operations Center. Each of the data packets provides an independent position fix for the vehicle. Overlaying the GPS position data provided by the TIDGET onto a digital map at the Operations Center identifies what road the vehicle is on and pinpoints its location on the road. Other GIS functions could also be performed to determine, for instance, the nearest emergency center.

**CONCLUSION**

The proposed TIDGET Mayday system has the following major advantages over any current competing technology.

- Low cost to the user due to the simplicity of the TIDGET sensor
- Reliable operation even in degraded satellite visibility
- Rapid response as no warm-up or initialization time required
- GPS coverage over the complete United States.
To minimize the cost of developing a Mayday system infrastructure, the proposed system architecture takes advantage of the existing mobile communications infrastructure. This also opens up commercial opportunities for value-added services to be offered in addition to the emergency functions. The TIDGET sensor can also be used to provide location information for AAA service calls, fleet management, or stolen car recovery. The system can even be used to provide a navigation or tourist information service, providing information and directions to the motorist on local hotels, restaurants, or campsites. The revenue generated by these value-added services can allow the Mayday service to be operated on a self-sustaining commercial basis.

NAVSYS is currently developing a prototype TIDGET Mayday sensor for installation in an automobile integrated with a cellular phone. This will be used to perform a field demonstration of the Mayday sensor in cooperation with the Colorado Department of Transportation.

REFERENCES


